Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

XXIX.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD COLLEGE.

No. XIII. — ON THE INTENSITY OF TERRESTRIAL MAGNETISM AT CAMBRIDGE.

By Henry Goldmark.

Presented April 10, 1878.

As the intensity of the force of the earth's magnetism has not been determined in Cambridge for many years, it was thought that a measurement of its magnitude might prove of some interest. I measured only the horizontal component and the inclination, and deduced the value of the vertical component from these.

To obtain the *horizontal component*, I made use of Gauss's method of oscillations, using the torsion balance made for this purpose by Edelmann, of Munich. Two quantities are determined, the product MH of the horizontal intensity H and the magnetic moment M of the magnet used, and the ratio $\frac{M}{H}$ of these two quantities.

To get MH, the time of oscillation of a small cylindrical magnet, suspended by a silk thread, was determined by means of a mirror and scale. The number of complete oscillations and fractions of an oscillation which this magnet made in one minute of time when vibrating under the influence of the magnetic force was observed, and from this the time t of a single oscillation was easily obtained. The amplitude of vibration was in every case so small that the usual reduction to an infinitely small arc was found to be unnecessary.

The *coefficient of torsion* Θ of the thread was in every case found by turning the upper circle through an angle of 90°, observing the angular deflection (φ) from the magnetic meridian produced in the suspended magnet, and substituting this value in the equation

$$\Theta = \frac{\phi}{90^\circ - \phi}$$

The small cylindrical magnet was carefully measured by means of a dividing-engine.

For the diameter, I found

North end. Mean of five measurements $d = 14.395$ mms.
South end. „ „ „ $d = 14.399$ „
Giving as the mean diameter $d = 14.397$ „

The length was given as the average of five measurements equal to 49.448 mms.

The weight was 62109.2 milligrams.

If, now, following Rankine, we use the weight instead of the mass in determining the moment of inertia, we get

if $l =$ length of the cylinder and
$r =$ its radius

$$I = W\left(\frac{l^2}{12} + \frac{r^2}{4}\right) = 62109.2\left(\frac{(49.448)^2}{12} + \frac{(7.198)^2}{4}\right)$$
$$= 13459758.5 \text{ mms. mgms.}$$

We have, then, all the data to get the value of MH which is given by Gauss's formula

$$MH = \frac{\pi^2 I}{t^2 (1 + \Theta)}. \qquad \text{(A.)}$$

To get $\frac{M}{H}$, I suspended a small magnet carrying a plane mirror from the centre of the apparatus, and measured the deflections produced by the cylindrical magnet described above, when placed at two points to the east and to the west. Using both poles in each position gives eight measurements. I also made a few observations with a box compass, but the results were by no means as precise or accurate as those obtained by suspension.

If, now, φ and φ' are the angular deviations from the meridian produced by the magnet at the distances r and r', and if

$\Theta =$ the coefficient of torsion of the thread, we have

$$\frac{M}{H} = \tfrac{1}{2}\,\frac{r^5 \tan\phi - r_1 \tan\phi_1}{r^2 - r_1{}^2}(1 + \Theta); \qquad \text{(B.)}$$

and we easily see that

$$H = \sqrt{MH \div \frac{M}{H}}.$$

The *inclination* or *dip* was determined according to the method given by Weber (Poggendorff's Annal. XC.), by the strength of the inductive currents produced in a coil of copper wire, rotated in such a way that only one of the two components of the earth's magnetism acts upon it at one time. I first placed a coil vertically in the meridian and turned it 90° around a vertical axis, having connected the ends of the wire with a Thomson reflecting galvanometer. The horizontal lines of magnetic force are the only ones cut by the coil, and hence the scale reading is proportional to H.

In the next place, I turned the coil, again placed vertically on the meridian, 90° around an horizontal axis. In this case, the vertical component is cut, and a deflection proportional to it produced.

Therefore, we have found the ratio of the two components; and, if i = the inclination, we have

$$\tan i = \frac{V}{H}; \tag{C.}$$

The results of my measurements are given below.

PRELIMINARY MEASUREMENTS, DEC. 19 AND 20, 1877.

(α) *Determination of MH.*

To find the time of oscillation t, two measurements were made as follows: —

Number of Observation.	Number of double oscillat. per minute.
I.	4.5
II.	4.509
	Mean 4.5045
which gives $t = 6.66$ secs.	

Θ was found equal to .01387.

Substituting these values in equation (A.), we get

$$MH = 2954000.$$

(β) *Determination of* $\frac{M}{H}$.

In this case, a ring-magnet was used, carrying a plane mirror, and suspended by a piece of silk thread, the torsion of which was measured, and gave

$$\Theta = .01719$$

The distance of the mirror from the scale was 1797 mms.

$r = 277$ mms.		$r_1 = 366$ mms.	
Position of deflecting magnet.	Deflection in scale divisions.	Position of deflecting magnet.	Deflection in scale magnets.
(1)	359.5	(5)	155.
(2)	354.	(6)	156.5
(3)	353.5	(7)	157.
(4)	359.5	(8)	152.5
	Mean 356.625		Mean 155.25
which gives $\phi = 5° 36' 45''$		which gives $\phi' = 2° 28' 8''$	

Substituting these values in (B.), we get

$$\frac{M}{H} = 1092495\,;$$

and combining with the value of *MH*,

$$H = \sqrt{\frac{2954000}{1092495}} = 1.6444$$

(γ) *Determination of the Dip.*

Six measures for each component were made, with the following results: —

Horizontal Component.		Vertical Component.	
Number of Observation.	Deflection on the scale.	Number of Observation.	Deflection on the scale.
I.	23	I.	86
II.	22	II.	88
III.	23	III.	88
IV.	23	IV.	87
V.	22	V.	87
VI.	23	VI.	87
	Mean 22.66		Mean 87.16

Hence

$$\tan i = \frac{87.16}{22.66};$$

which gives

$$i = 75^\circ \; 25' \; 30''.$$

MEASUREMENTS OF MARCH 20, 1878.

(α) *Determination of MH.*

To find t, 8 measurements were made, with the following results:—

Number of Observation.	Amplitude of Oscillation.	No of double Oscill. per min'te.	t.
I.	174	4.5581	6.5816
II.	147	4.4578	6.5821
III.	99	4.5606	6.5781
IV.	90	4.5556	6.5853
V.	67	4.5606	6.5781
VI.	61	4.5590	6.5804
VII.	52	4.5577	6.5823
VIII.	34	4.5583	6.5807
			Mean 6.5811

Θ was found equal to .01979;

and these values give

$$MH = 3005600.$$

(β) *Determination of* $\frac{M}{H}$.

I here used a very light magnet, consisting merely of three pieces of magnetized watchspring. A mirror and a piece of aluminum foil to stop the vibrations were used. It was suspended by a single fibre of silk about 400 mms. long. The torsion of this thread was imperceptible even on turning the upper circle through an angle of 360°.

Six complete measurements were made, with the following results. The distance of the scale from the mirror was 1516 mms.

$r = 277$ mms.			$r_1 = 366$ mms.	
Number of Measurement.	Position of Magnet.	Deflection in scale divisions.	Position of Magnet.	Deflection in scale divisions.
I.	(1)	308	(5)	136
	(2)	312	(6)	135.5
	(3)	311	(7)	135
	(4)	309	(8)	132.5
II.	(1)	311	(5)	135
	(2)	313	(6)	135
	(3)	311	(7)	136
	(4)	309	(8)	133
III.	(1)	312	(5)	135
	(2)	311	(6)	135
	(3)	313	(7)	135
	(4)	309	(8)	133
IV.	(1)	311	(5)	135
	(2)	312	(6)	135
	(3)	312	(7)	134
	(4)	309	(8)	133
V.	(1)	312	(5)	134.5
	(2)	310	(6)	135.5
	(3)	312	(7)	135
	(4)	311	(8)	133
VI.	(1)	310	(5)	135.5
	(2)	311	(6)	135
	(3)	311	(7)	135
	(4)	309	(8)	133
		Mean 310.7916		Mean 134.5625
which gives $\phi = 5^\circ\ 47'\ 34\tfrac{1}{2}''$			which gives $\phi' = 2^\circ\ 32'\ 10''$	

Substituting these values, I find

$$\frac{M}{H} = 1096016\,;$$

and hence

$$H = \sqrt{\frac{3005600}{1096016}} = 1.656.$$

(γ) *Determination of i.*

I used two different coils, with results that agreed very nearly, as shown by the table which follows: —

SMALLER COIL *A*.			LARGER COIL *B*.	
Number of Measurement.	H	V	H	V
(1)	45	10	86	22
(2)	44	12	87	22
(3)	43	10 5	85	22
(4)	45	12	86.5	21
(5)	44	11.5	87	22
(6)	43	12	87	23
	Mean 44	Mean 11.33	Mean 86.42	Mean 22

From A we get, then,

$$\tan i = \frac{11.33}{44} \qquad i = 75^\circ\ 33'\ 22''.$$

From B we get

$$\tan i = \frac{22}{86.42} \qquad i = 75^\circ\ 43'\ 3''.$$

The mean of these two values gives

$$i = 75^\circ\ 38'\ 12\tfrac{1}{2}''.$$

As our result, we have, then, for the force of magnetism on the 20th of March,

$$H = 1.656 \text{ mms. mgms.}$$

and

$$i = 75^\circ\ 38'\ 12\tfrac{1}{2}''.$$

And since

$$V = H \tan i,$$

we get

$$V = 6.4173.$$

NOTE. — To ascertain, at least approximately, the degree of correctness attained in this result, I computed the probable mean errors of the time of oscillation in the last determination. The table explains itself.

Number of Measurement.	t.	δ	δ^2
I.	6.5816	+ .0005	.00000025
II.	6.5821	+ .0010	.00000100
III.	6.5781	— .0030	.00000900
IV.	6.5853	+ .0042	.00001764
V.	6.5781	— .0030	.00000900
VI.	6.5804	— .0007	.00000049
VII.	6.5823	+ .0012	.00000144
VIII.	6.5807	— .0004	.00000016
	Mean 6.5811		$S = .00003898$

$$\text{The mean error of one observation} = \sqrt{\frac{.00003898}{7}} = \pm\ .00236$$

$$\text{„ „ „ the result} = \sqrt{\frac{.00003898}{7 \times 8}} = \pm\ .0008344$$

$$\text{The probable error of one observ'n.} = .67449 \sqrt{\frac{.00003898}{7}} = \pm\ .00159$$

$$\text{„ „ „ the result} = .67449 \sqrt{\frac{.00003898}{7 \times 8}} = \pm\ .00056278$$

I am indebted to Professor TROWBRIDGE for much kind advice and assistance in the course of my work.